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(54) **DEVICE COMPRISING N-CHANNEL SEMICONDUCTOR MATERIAL**

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(58) **Field of Search** 257/40, 288, 72

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,596,208	*	1/1997	Dodabalapur	257/40
5,757,032	*	5/1998	Nishibayashi	257/77
5,853,905	*	12/1998	So	257/40
5,998,803	*	12/1999	Forrest	257/40

OTHER PUBLICATIONS

A. Dodabalapur, et al. "Organic Heterostructure Field–Effect Transistors", *Science*, vol. 269, pp. 1560–1562 (1995).
F. Garnier, et al. "Structural basis for high carrier mobility in conjugated oligomers", *Synthetic Metals*, vol. 45, pp. 163–171 (1991).
A.R. Brown, et al. "Logic Gates Made from Polymer Transistors and Their Use in Ring Oscillators", *Science*, vol. 270, pp. 972–974 (1995).
F. Garnier, et al. "All–Polymer Field–Effect Transistor Realized by Printing Techniques", *Science*, vol. 265, pp. 1684–1686 (1994).
H.E. Katz, "Organic molecular solids as thin film transistor semiconductors", *J. Mater. Chem.*, vol. 7, No. 3, pp. 369–376 (1997).
H.E. Katz, et al. "Oligo–and Polythiophene Field Effect Transistors", Chapter 9, *Handbook of Oligo–and Polythiophenes*, D. Fichou, ed., Wiley–VCH (1999).
A. Dodabalapur, et al. "Complementary circuits with organic transistors", *Appl. Phys. Lett.* vol. 69, No. 27, pp. 4227–4229 (1996).
M.A. Alam, et al. "A Two–Dimensional Simulation of Organic Transistors", *IEEE Transactions On Electron Devices*, vol. 44, No. 8, pp. 1332–1337 (1997).
J.G. Laquindanum, et al. "n–Channel Organic Transistor Materials Based on Naphthalene Frameworks", *J. of the American Chemical Society*, vol. 118, No. 45, pp. 11331–11332 (1996).
M. Adachi, et al. "Spectral Similarity and Difference of Naphthalenetetracarboxylic Dianhydride, Perylenetetracarboxylic Dianhydride, and Their Derivatives", *J. Phys. Chem.*, vol. 99, pp. 14240–14246, (1995).
U.S. application Serial No. 08/729304, filed Oct. 15, 1996.

* cited by examiner

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(57) **ABSTRACT**

The invention provides a device comprising an improved n-channel semiconducting film, the film formed from a fused-ring tetracarboxylic diimide compound which exhibits a field effect electron mobility greater than 0.001 cm^2/Vs, advantageously greater than 0.03 cm^2/Vs, in film form. Contemplated compounds include naphthalene 1,4,5,8 tetracarboxylic acid diimides, naphthalene 2,3,6,7 tetracarboxylic acid diimides, anthracene 2,3,6,7-tetracarboxylic acid diimides, and heterocyclic variants thereof. The n-channel compounds are capable of being significantly soluble in common organic solvents, allowing for solution deposition of active semiconductor films, and are also capable of possessing significant volatility, such that vapor phase deposition, where desired, is relatively facile. It is also possible for the compounds to display the desirably high n-channel mobilities and on/off ratios even when operated in air.

20 Claims, 1 Drawing Sheet